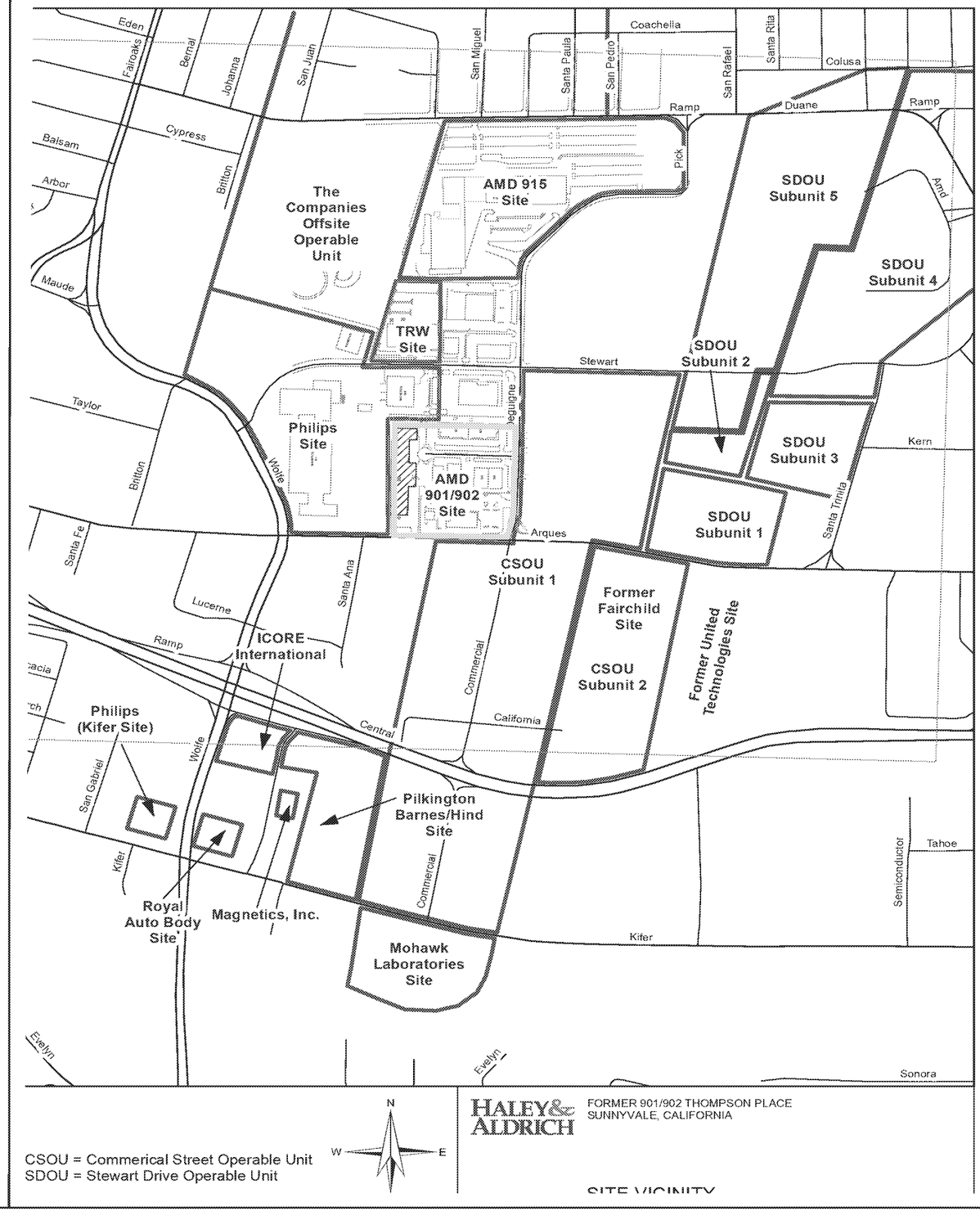
SITE SETTING

- Former AMD facility located at 901 and 902 Thompson Place in Sunnyvale, CA, for semiconductor fabrication beginning in 1969. Leaks from tanks led to TCE detections in soil and groundwater, along with breakdown products.
- Area includes many current and former industrial and manufacturing facilities, including semiconductor fabrication.
- Nearby groundwater cleanup sites which have the same primary COCs as the AMD site (TCE and cDCE) include the former Signetics (Philips) site, TRW Microwave site, AMD 915 DeGuigne Drive site, Mohawk Laboratories site, and the Companies Offsite Operable Unit (OOU).
- The AMD 901/902 Thompson Place site, Signetics (Philips) site, and TRW Microwave site are part of the "Triple Site" (with the Off-Site Operable Unit or OOU) under a single ROD.

Overview of Regional Parties Site Boundaries:



CSOU = Commerical Street Operable Unit
SDOU = Stewart Drive Operable Unit

N
W
E

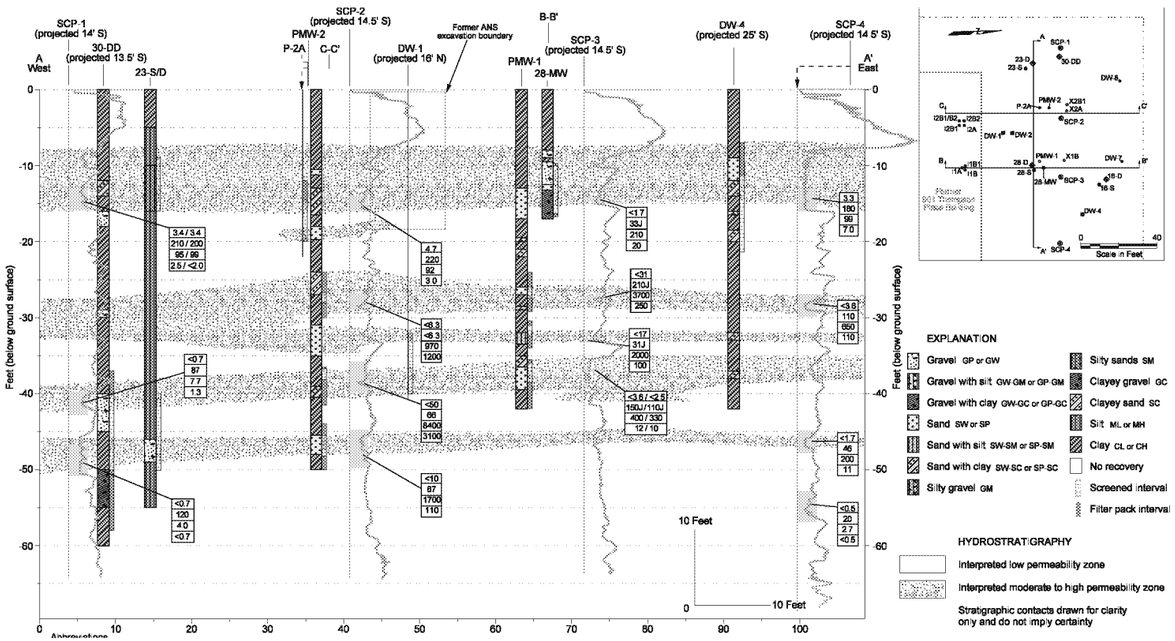
HALEY & ALDRICH

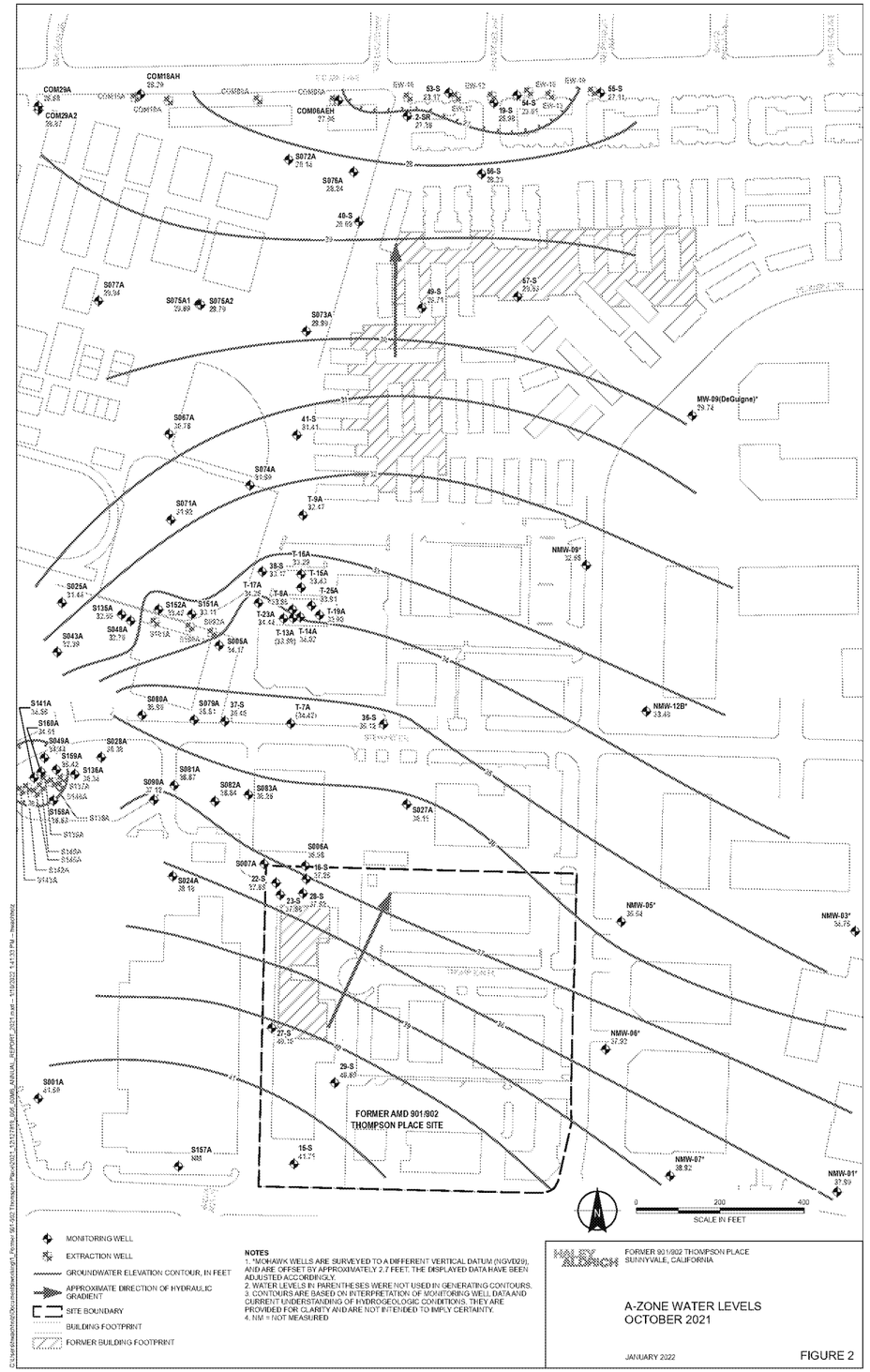
FORMER 901/902 THOMPSON PLACE
SUNNYVALE, CALIFORNIA

SITE VICINITY

SITE HYDROGEOLOGY

- The horizontal hydraulic gradient trends to the north northeast.
- The Site's hydrostratigraphy includes a sequence of coarse-grained sediments separated primarily by silty clay. From shallow to deep, the primary hydrostratigraphic zones are the A, B1, B2, and B3 zones. The depth intervals designated for each zone are not consistent among many of the early reports on Site hydrogeology. Different interpretations of depth intervals for various zones likely occurred because of the complex nature of the alluvial system beneath the Site, in which sand zones comprise elongated, channel-type deposits that can occur at various depths and widths, with a meandering three dimensional configuration, rather than a series of horizontal, continuous layers.
- A-Zone wells are generally screened from 10 to 25 feet bgs; B1-Zone wells are generally screened from 25 to 45 feet bgs; B2-Zone wells are generally screened from 45 to 55 feet bgs; and the one B3-Zone well is screened from 70 to 80 feet bgs.

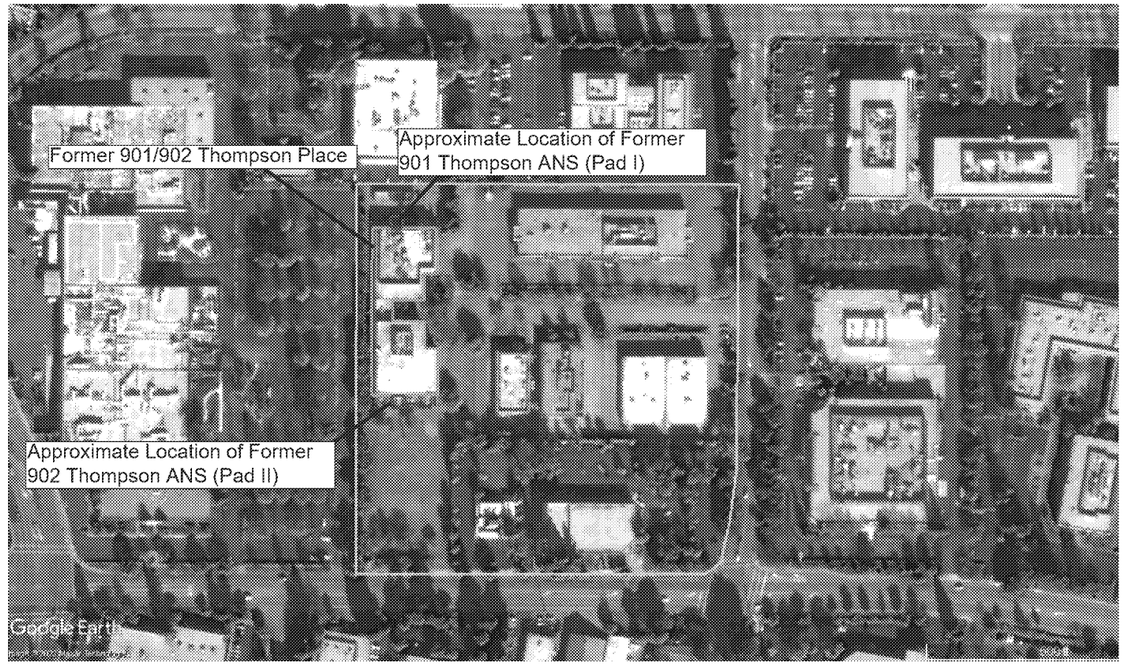




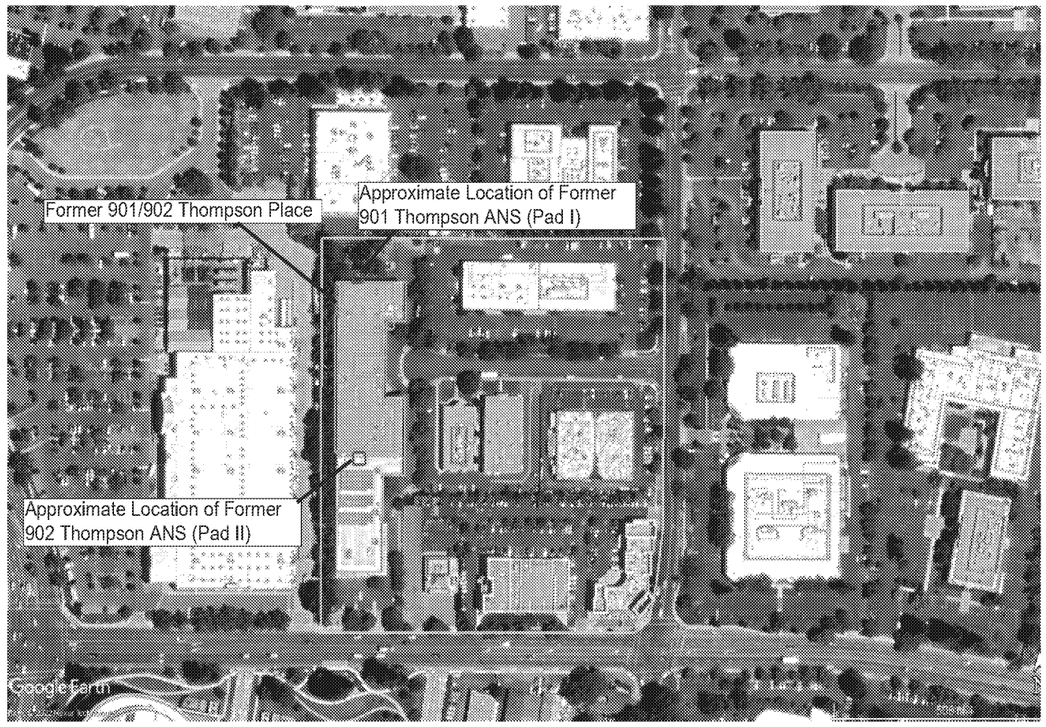
SITE OPERATIONAL HISTORY

- AMD designed and fabricated semiconductor devices between 1969 and 1992.
- Use of solvents and corrosives in the fabrication process; TCE use is inferred from 1969 to 1979.
- There were two acid neutralization systems (ANS) at the north and south ends of the buildings. The main source of TCE impacts appears to be from leaks in the ANS tanks over time. The tanks were removed in 1983/1984.
- AMD ceased operations in 1992, and sold the property to Summit Commercial Properties in 2007. The site was redeveloped as a three-story self-storage facility (with the new address of 875 East Arques Avenue).

Aerial view before site redevelopment and source areas:



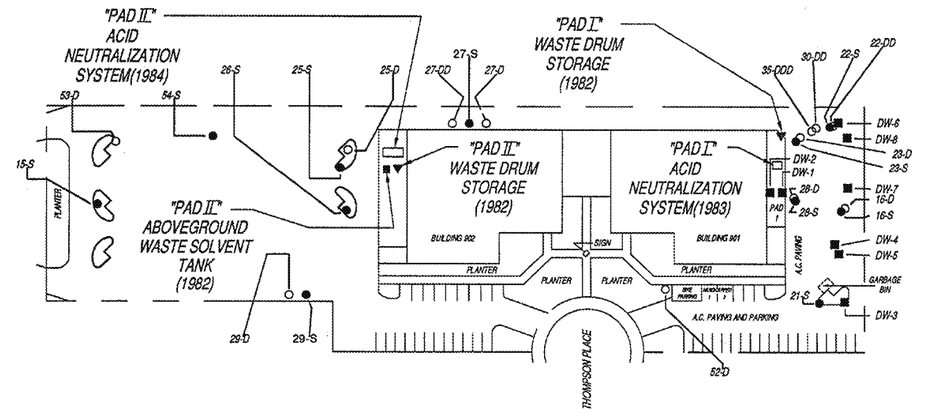
Aerial view after site redevelopment and source areas:



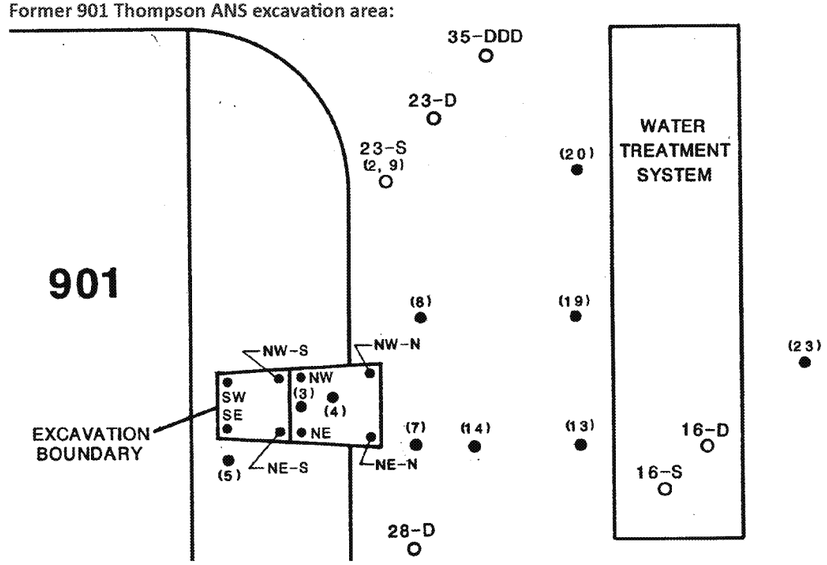
INVESTIGATION/REMEDIATION HISTORY

- 1982 – Initiation of groundwater monitoring.
- 1983 – Groundwater extraction and treatment begins using air stripping.
- 1983 – Soil investigation at 901 Thompson Place (north of building).
- 1983 – Removal of 901 Thompson Place acid neutralization system (ANS) and soil excavation.
- 1984 – Soil investigation near south end of 902 Thompson Place building.
- 1984 – Removal of 902 Thompson Place ANS and soil excavation.
- 1988 – Additional soil investigation at 901 Thompson Place.
- 1989 – Soil gas investigation.
- 1992 – Additional soil excavation of former 901 ANS.
- 2002 – Subsurface investigation in area of former 901 Thompson Place ANS.
- 2002 – Groundwater extraction and treatment system shut down to allow for ISB pilot test.
- 2002-2004 – In situ bioremediation (ISB) pilot test.
- 2005 – Additional subsurface investigation. Full-scale ISB Program begins.
- 2008 – Water Board approves soil remediation and grants a No Further Action letter for soil remediation.
- 2008 – The Full-scale ISB Program is converted from an active to a passive program, where ongoing intrinsic bioremediation is monitored on a quarterly basis.
- 2011-2020 – Pulsed operation of the ISB system to increase organic carbon content in the subsurface.
- 2013 – Indoor air investigation to evaluate vapor intrusion on-Site. Haley & Aldrich concluded that COCs present in groundwater are not impacting indoor air quality.

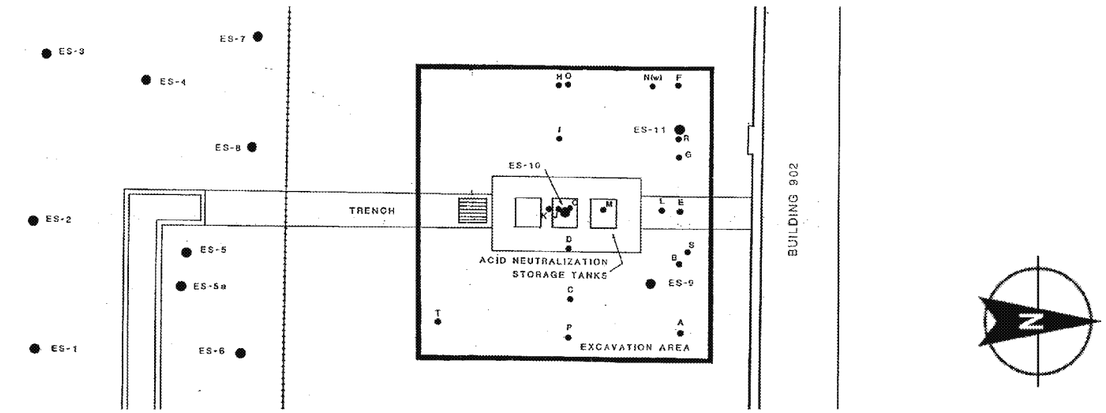
Historical waste storage areas:



Former 901 Thompson ANS excavation area:

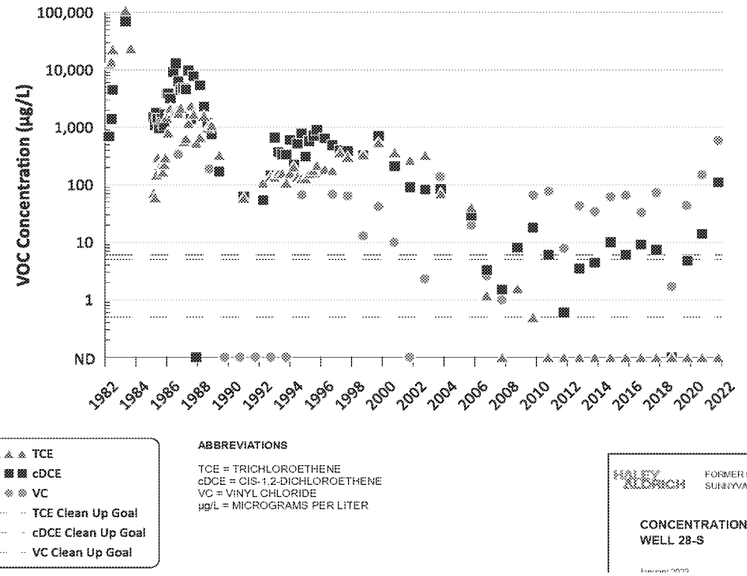


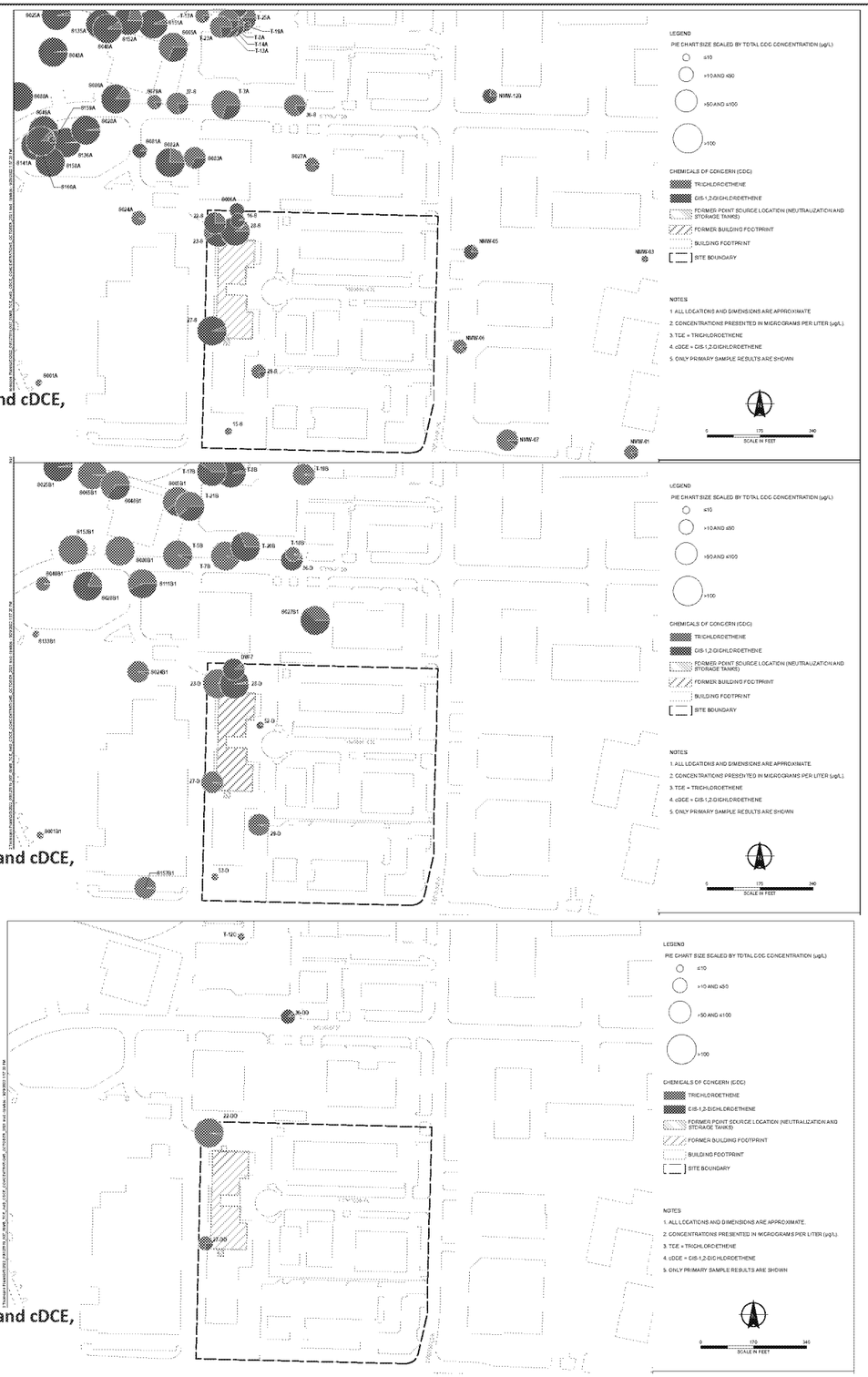
Former 902 Thompson ANS excavation area:



DISTRIBUTION OF PRIMARY COCs

- TCE and cDCE are the primary COCs for the Site. VC has also been detected in groundwater within the ISB treatment area (VC is an interim breakdown product of TCE and cDCE during the microbially-mediated reductive dechlorination to ethene).
- The 901 Thompson Site is located in a region with many groundwater cleanup sites with historical concentrations of TCE and cDCE.
- The ISB area is the location of the former source area, and historically has had the highest COC concentrations. Concentrations have decreased substantially (up to several orders of magnitude) since the start of remediation.
- The wells cross- and upgradient of the former source areas (e.g., located to the west, east, and south of the former 901/902 Thompson buildings) are impacted by upgradient, off-Site sources. These sources will continue to impact groundwater flowing beneath the Site for the foreseeable future.
- In the three downgradient, off-Site monitoring wells (36-S, 36-D, and 36-DD), COC concentrations are consistent with or lower than the range of concentrations observed in the ISB treatment area.





A-Zone TCE and cDCE, October 2021

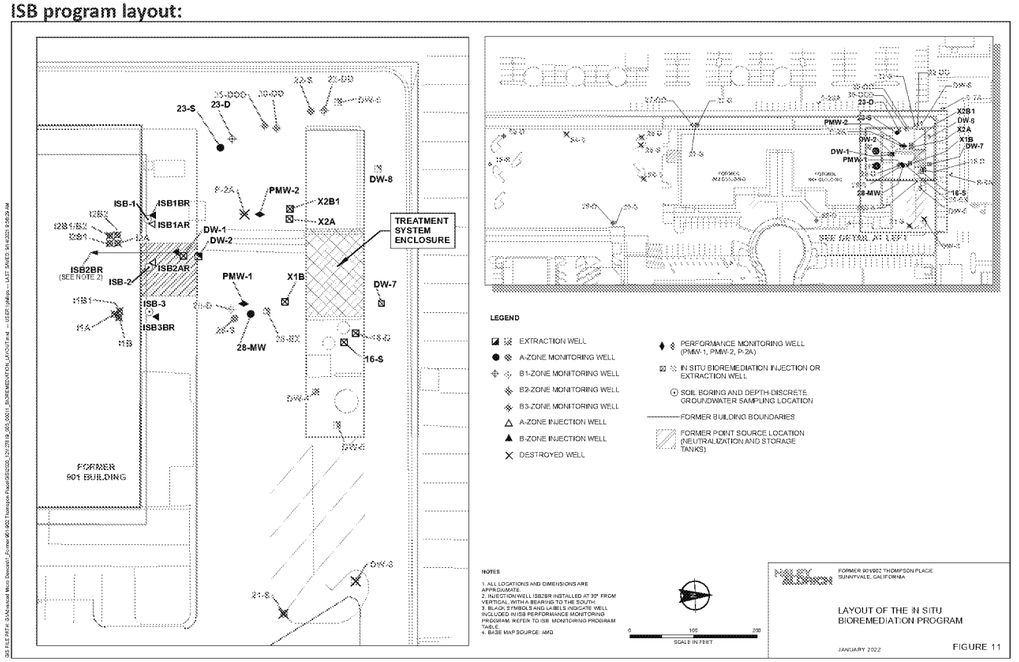
B1-Zone TCE and cDCE, October 2021

B2-Zone TCE and cDCE, October 2021

REMEDIATION

- The former 901 and 902 ANS were removed and soil excavated in 1983 and 1984. Additional soil was removed from the former 901 ANS area in 1992. The 902 ANS was not likely a significant source of COCs (e.g., low TCE concentration in soil, low TCE concentration in the excavation pit relative to nearby wells, and no decrease in TCE concentration in wells downgradient of the ANS post-excavation).
- A GETS was installed north of the former 901 building with extraction wells near the former 901 ANS and at the downgradient (northern) property boundary. The GETS began operating in 1983 and was shut down in 2002 to implement the ISB pilot test.
- An ISB pilot study was conducted beginning in 2002 to evaluate ISB as an alternative groundwater cleanup strategy towards expediting groundwater cleanup. Based on the success of the pilot test, a full-scale ISB program was initiated in 2005 with Water Board approval.
- The mass removal efficiency using ISB initially far exceeded that during GETS operation; decreasing influent concentrations are driving lower removal efficiency during the more recent ISB operations.

ISB program layout:



GETS and ISB mass removal summary:

Mechanism	Volume Extracted[1] (gallons)	Average Influent VOCs (µg/L)	Estimated Total VOCs Removed (pounds)	Extraction System Efficiency (lb/MG)
1983/1984 Excavations	NA	NA	10	NA
1992 Excavation	NA	NA	0.3	NA
Groundwater Extraction				
1984 through 1995[2,3]	126,940,000	529	559	4.4
Groundwater Extraction				
1996	16,140,000	283	38	2.4
1997	15,817,920	339	45	2.8
1998	16,636,170	277	38	2.3
1999	16,170,000	251	33	2.0
2000	12,291,830	262	27	2.2
2001	13,032,970	281	29	2.2
2002	13,495,145	363	40	2.9
SUBTOTALS[3]	**103,584,035**	**294**	**250**	**2.4**
2006	586,929	1,287	5.9	10.1
2007	154,649	2,653	3.0	19.5
2008	291,553	539	1.3	4.5
2009[4]	0	NA	0.0	NA
2010[4]	0	NA	0.0	NA
2011	109,204	1,113	1.0	9.3
2012	205,125	761	1.3	6.3
2013	114,370	721	0.7	6.0
2014	80,338	145	0.1	1.2
2015[4]	0	NA	NA	NA
2016	64,010	147	0.1	1.2
2017	74,609	251	0.2	2.1
2018[5]	82,527	340	0.2	2.8
SUBTOTALS[3]	**1,763,314**	**796**	**14**	**6.3**

IN SITU BIOREMEDIATION

- While intrinsic bioremediation is occurring, higher concentrations of COCs have been observed in wells where TOC is depleted. Therefore, groundwater circulation and substrate amendment has been conducted periodically to add organic carbon to the subsurface and promote ISB.
- Different types of organic carbon substrates have been implemented and evaluated with regard to their ability to be distributed in the subsurface and their effectiveness at promoting reductive dechlorination of COCs.
- The ISB system has had limited ability to deliver the substrate to certain wells, due in large part to the heterogeneous nature of the A and B Zones.
- AMD implemented several modifications to the ISB system to improve the effectiveness of substrate delivery and continued COC concentration decreases, e.g., well rehabilitation, use of soluble substrates.

SUMMARY OF ISB SYSTEM HISTORICAL OPERATIONS
FORMER 901/902 THOMPSON PLACE
SUNNYVALE, CALIFORNIA

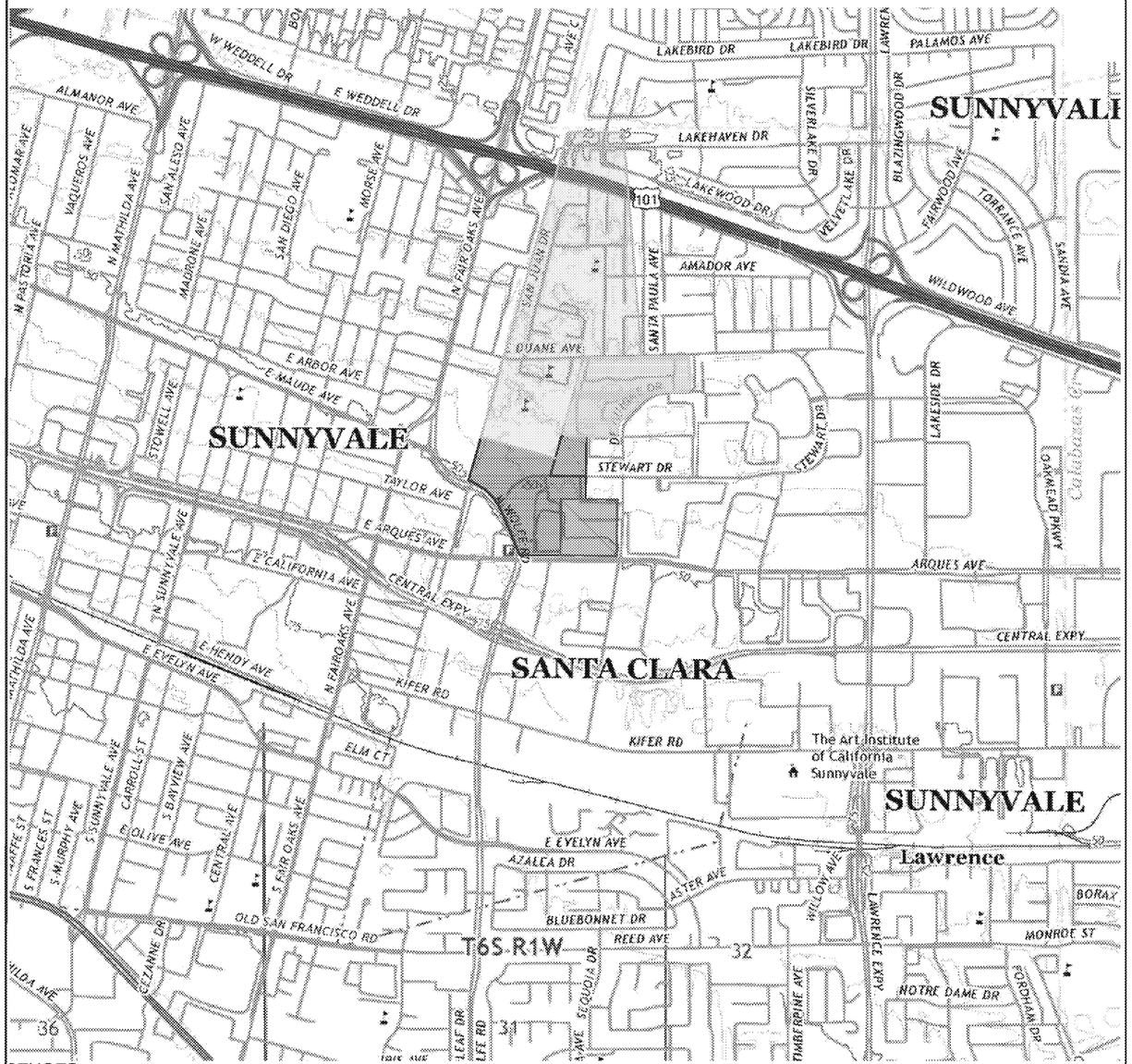
ISB Operation Event Period and Days Operated	Substrate Type	Quantity of Substrate Solution Injected	Substrate Delivery Method
December 2005 to May 2008 (449 days)	Molasses	2,495 gallons	Extracted groundwater mixed in-line with substrate (added using a metering pump) and pumped into injection wells
October 2011 to February 2012 (114 days)	Molasses	275 gallons	Extracted groundwater mixed in-line with substrate (added using a metering pump) and pumped into injection wells
November 2012 to February 2013 (99 days)	Molasses	276 gallons	Extracted groundwater mixed in-line with substrate (added using a metering pump) and pumped into injection wells
January to June 2014 (56 days)	60 percent sodium lactate solution	144 gallons	Substrate added directly into injection wells, followed by groundwater recirculation
January to February 2016 (29 days)	Emulsified vegetable oil solution (nutrient-enriched 60 percent vegetable oil/4 percent sodium lactate solution)	268 gallons	Mixed in bulk with extracted groundwater in aboveground storage tanks and pumped into injection wells
May to June 2017 (27 days)	60 percent sodium lactate solution	165 gallons	Extracted groundwater mixed with substrate (added using a metering pump) in aboveground tanks and pumped into injection wells
May to June 2018 (41 days)	Combination of 60 percent sodium lactate solution and nutrient-enriched 30 percent potassium lactate solution	202 gallons	Extracted groundwater mixed with substrate (added using a metering pump) in tanks and pumped into injection wells
April to May 2019 (49 days)	Combination of 60 percent sodium lactate solution and nutrient-enriched 30 percent potassium lactate solution	339 gallons	Extracted groundwater mixed with substrate (added using a metering pump) in tanks and pumped into injection wells
June to August 2020 (65 days)	Provect ERD CH4+ (contains fermentable organics, micronutrients, antimethanogenic reagents, and a ferrous iron supplement)	293 gallons	Two methods: (1) Extracted groundwater mixed with substrate (added using a metering pump) in tanks and pumped into injection wells, and (2) substrate added directly into injection wells

Notes:
ERD = Enhanced Reductive Dechlorination
ISB = In situ bioremediation
1. Days operated is based on hours that groundwater circulation occurred, with or without substrate amendment. The maximum duration is presented in this table for periods when the system operated longer in one zone than the other zone.
2. The substrate quantity is the sum of quantities injected into the A Zone and B Zone.

RECORD OF DECISION (ROD) AMENDMENT

- The selected remedy in the ROD is groundwater extraction and treatment.
- The GETS was shut down in 2002 to facilitate ISB pilot test, and has remained off during full-scale ISB
- AMD submitted a Focused Feasibility Study (FFS) in 2011 recommending the remedy be revised to ISB and MNA (via a ROD Amendment). A revised FFS was submitted in 2013.
- Conversations with previous EPA remedial manager (Melanie Morash) indicated EPA was in agreement with the proposed change, but document has not yet been approved.
- Approval and ROD Amendment would wait until similar FFS reports could be completed for the TRW and Philips site, so that only one ROD Amendment is needed (since the sites are all under the same ROD).
- The other sites are in varying stages of pilot testing alternative remedies (such as ISB) or preparing FFS.

Location of Triple Site



RENCES:

. 7.5-MINUTE TOPOGRAPHIC MAP FOR MOUNTAIN VIEW, CA 2018
. 7.5-MINUTE TOPOGRAPHIC MAP FOR MILPITAS, CA 2018
. 7.5-MINUTE TOPOGRAPHIC MAP FOR CUPERTINO, CA 2018
. 7.5-MINUTE TOPOGRAPHIC MAP FOR SAN JOSE WEST, CA 2018
GHT UNITED STATES GEOLOGICAL SURVEY, 2018
HED DATE: 2018-09-14, METADATA UPDATED: 2018-09-21

MAP LEGEND:

- THE COMPANIES OFFSITE OPERABLE UNIT
- SIGNETICS SITE
- AMD 901/902 SITE
- AMD 915 SITE
- TRW MICROWAVE SITE

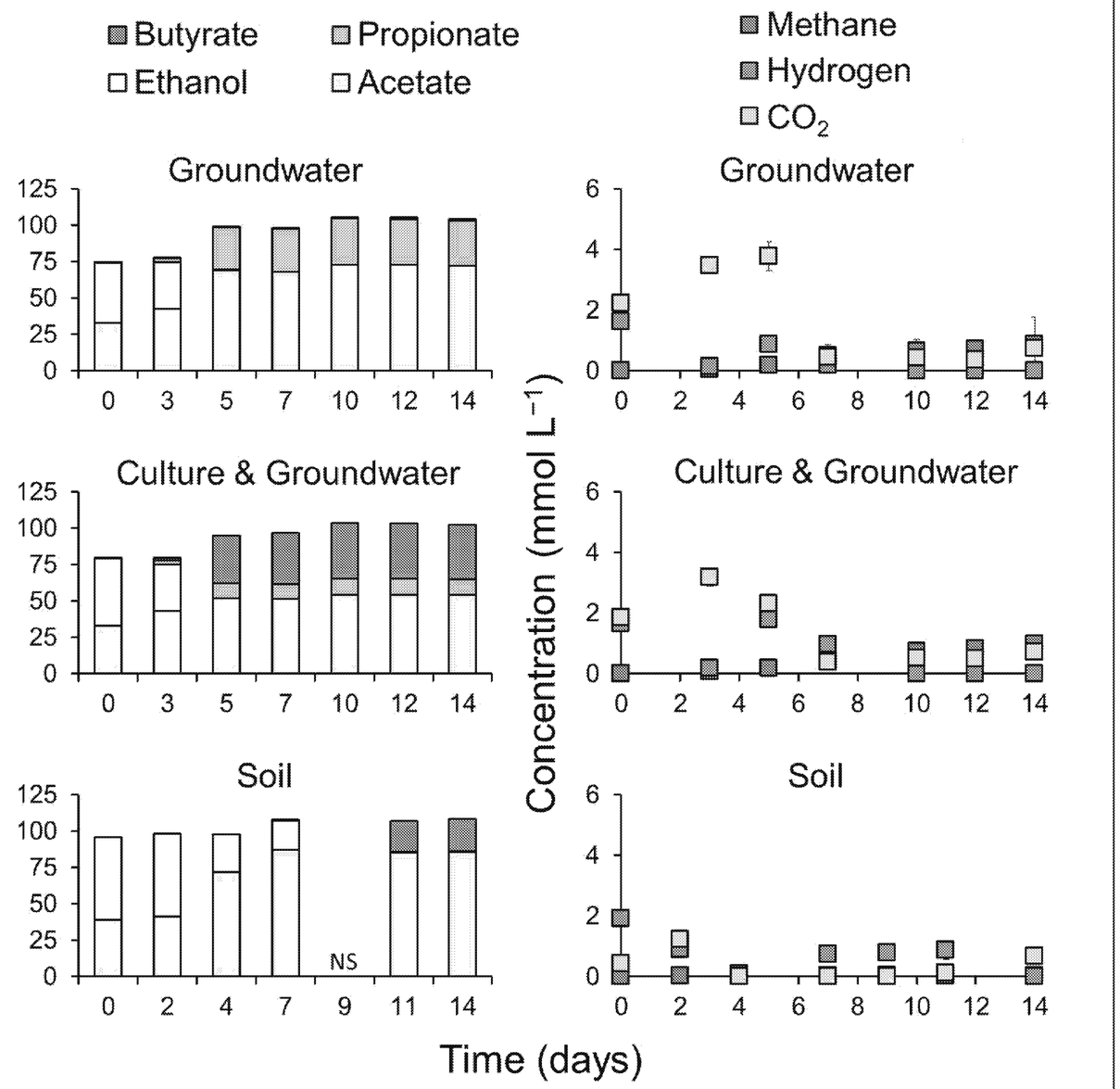
SITE LOCATION MAP

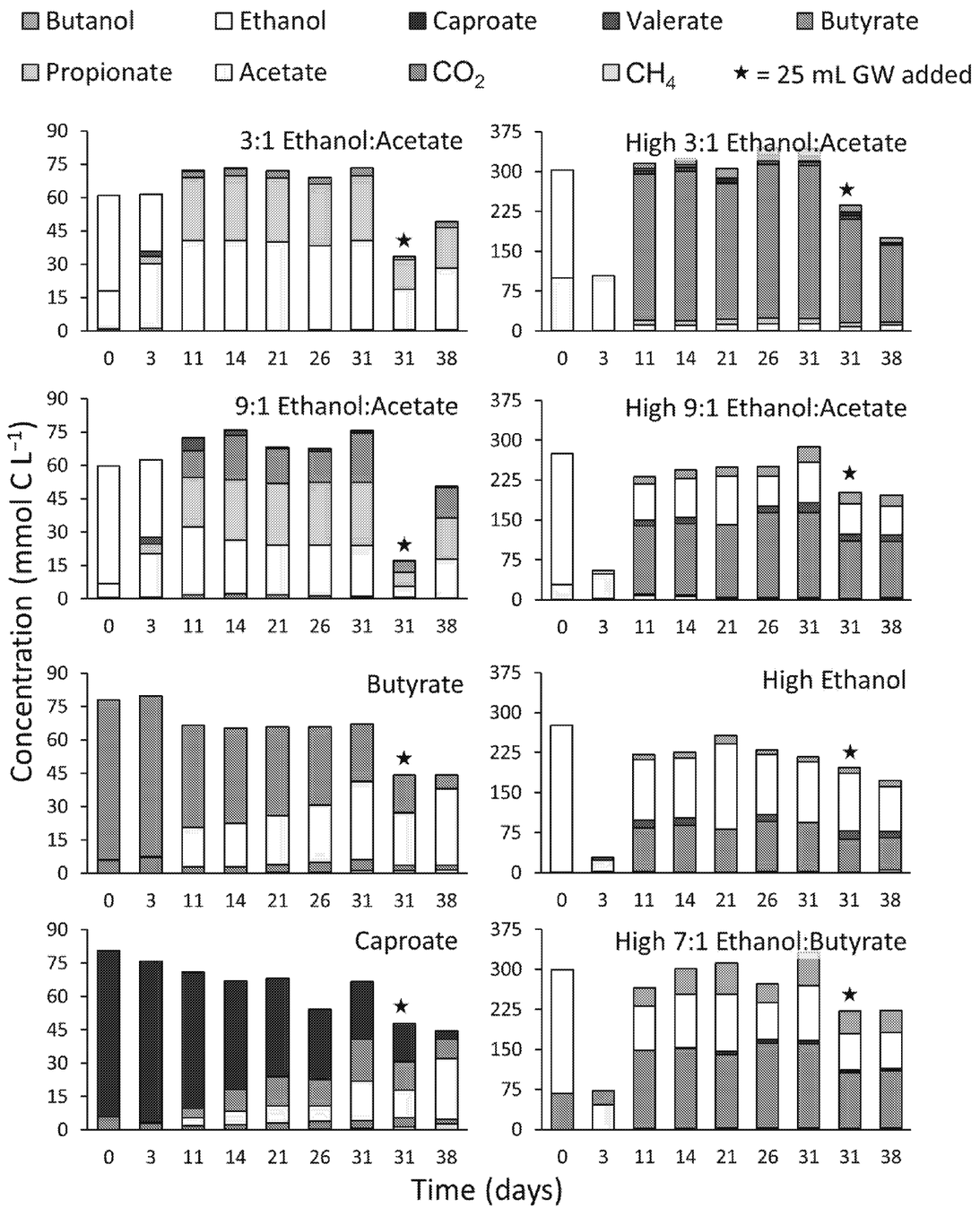
SIGNETICS SITE
AND OFFSITE OPERABLE UNIT
SUNNYVALE, CALIFORNIA

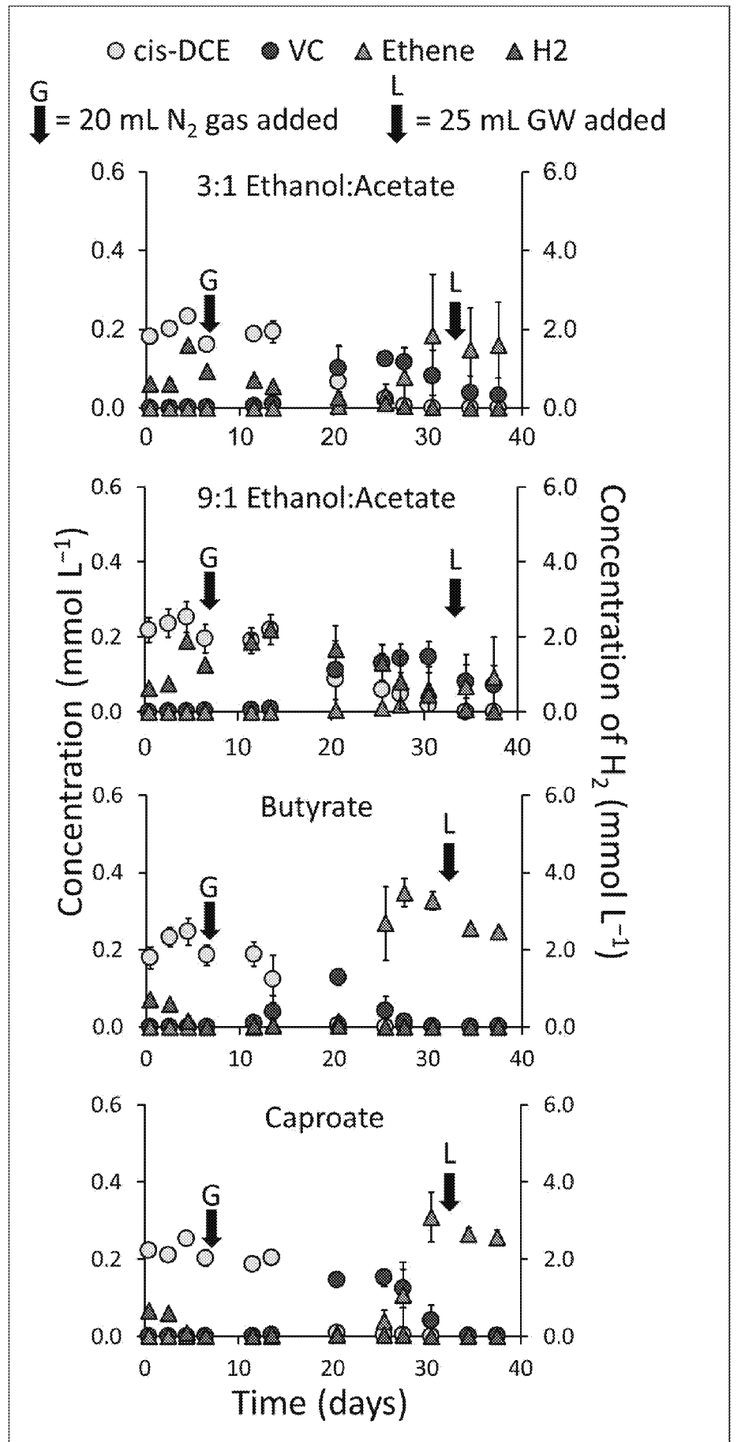
0 2,000
SCALE IN FEET

MODIFICATIONS TO ISB APPROACH

- While ISB is effective at treating chlorinated VOCs, there are several common issues:
  - Soluble substrates (e.g., lactate) are rapidly consumed, requiring more frequent amendments.
  - Longer-lasting substrates (e.g., EVO) can clog injection wells and surrounding formation.
  - Many amendments result in biogenic methane formation.
- H&A, AMD teamed with Arizona State University to evaluate a different ISB mechanism that can potentially address these drawbacks: microbial chain elongation, or MCE.
  - Specific bacteria take short-chain compounds (acetate and ethanol) and create longer-chain compounds (butyrate, caproate, and others). This process releases hydrogen, which drives biological dechlorination.
  - These compounds can then be fermented by other bacteria, which serves as a slow-release hydrogen source.
  - This pathway would not benefit methanogenic bacteria, reducing methane generation.
  - The precursors (acetate and ethanol) are soluble, aiding in distribution and mitigating well clogging.
- Laboratory Bench-scale microcosm testing conducted at ASU with Site media in 2021, results presented to EPA's Office of Research and Development.
  - Acetate and ethanol were successfully transformed into caproate and butyrate.
  - Complete dechlorination of cDCE to ethene was observed.
  - Methane concentrations did not substantially increase.
  - While MCE bacteria were present in shallow Site soil, bioaugmentation was needed in groundwater samples to achieve MCE and reduce cDCE to ethene.

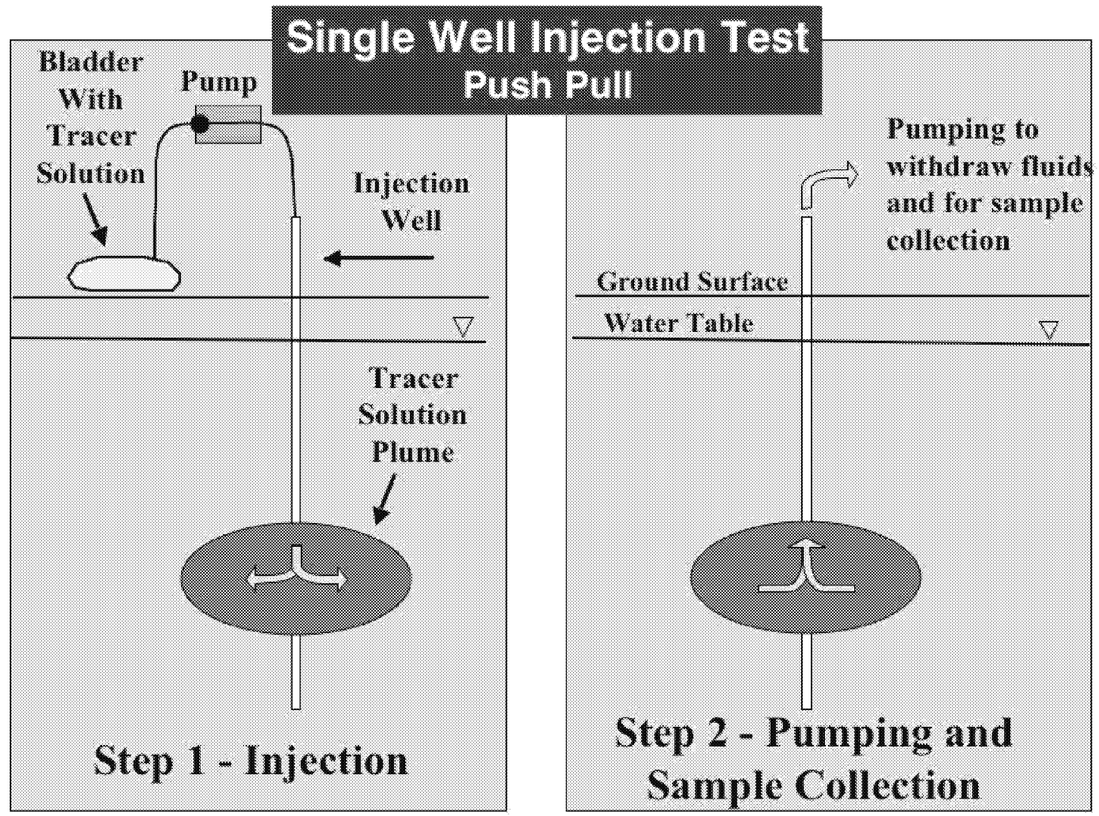



Butanol
Ethanol
Caproate
Valerate
Butyrate
Propionate
Acetate
CO_2
CH_4
★ = 25 mL GW added
3:1 Ethanol:Acetate
High 3:1 Ethanol:Acetate
9:1 Ethanol:Acetate
High 9:1 Ethanol:Acetate
Butyrate
High Ethanol
Caproate
High 7:1 Ethanol:Butyrate
Concentration (mmol C L^{-1})
Time (days)


cis-DCE
VC
Ethene
H2
G = 20 mL N_2 gas added
L = 25 mL GW added
3:1 Ethanol:Acetate
9:1 Ethanol:Acetate
Butyrate
Caproate
Concentration (mmol L^{-1})
Concentration of H_2 (mmol L^{-1})
Time (days)

MODIFICATIONS TO ISB APPROACH

- Field test of MCE (push-pull test) is being developed
  - Water with no VOCs (DW-2) will be amended with acetate, ethanol, and a tracer compound
  - This water will be injected into the subsurface in an area with no VOCs (the “push”)
  - Samples will be collected over time to evaluate if MCE processes are occurring, and if so, how rapidly.
  - After a set amount of time the injected water will be extracted (the “pull”)
  - If no MCE processes are observed, the test will be repeated, but with a bioaugmentation culture.
  - A final test will be to use water with VOCs (DW-1), amend it as above, and inject. This test will be to the rate of dechlorination to ethene and methane generation.



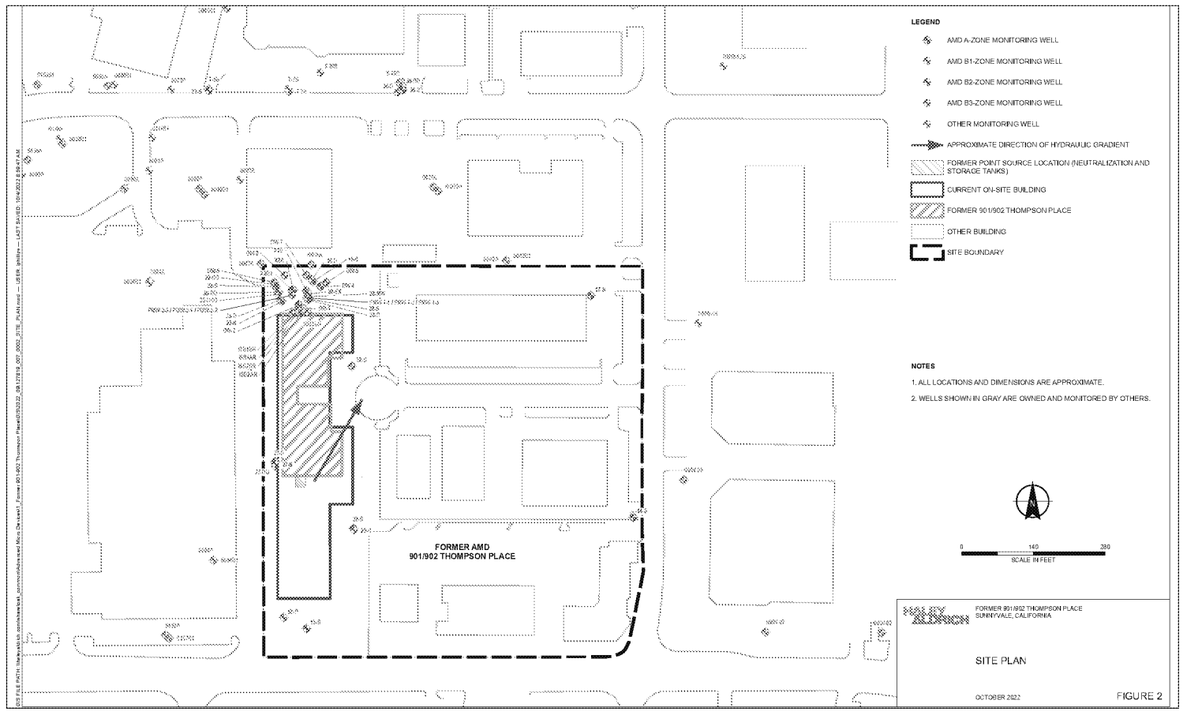
Current Scope of Work

- Annual groundwater monitoring and reporting – Annual groundwater monitoring events timed to coincide with other nearby groundwater cleanup Sites. Water level and analytical data shared with other regional PRPs. Reports due January 31.
- Periodic recirculation and substrate amendment
- Semiannual ISB performance monitoring and reporting – Semiannual performance monitoring events, typically in February and August. Reports due April 30 and October 30.
- ISB substrate evaluation and MCE pilot test

Regional COCs:

Compound	901 Thompson COC	915 DeGuigne COC	TRW COC	Philips COC	OOU COC	Mohawk COC (CSOU 1&2)
Benzene		x				
Total Chromium (III & VI)		x				
Chloroform		x				
Dichlorodifluoromethane		x				
1,1-Dichloroethane	x	x		x	x	
1,1-Dichloroethene	x	x	x	x	x	
cis-1,2-Dichloroethene	x	x	x	x	x	x
trans-1,2-Dichloroethene	x	x	x	x	x	x
Ethylbenzene		x				
Freon 113	x	x	x	x	x	x
Tetrachloroethene	x	x	x		x	x
Toluene		x				
1,2,4-Trichlorobenzene		x				
1,1,1-Trichloroethane	x	x		x	x	
Trichloroethene	x	x	x	x	x	x
Trichlorofluoromethane		x				
Vinyl Chloride	x	x	x	x		x
Xylenes		x				
1,2-Dichlorobenzene	x		x			x
1,1-Dichlorobenzene			x			
TPH-g & TPH-d						x
1,4-Dichlorobenzene						x (GW)
Chlorobenzene						x (Soil)
1,3-Dichlobenzene						x (Soil)

Site Plan after redevelopment:



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